Long-Term Monitoring of the Navy's Manchester Eelgrass Bed

Laurie Weitkamp
Northwest Fisheries Science Center, National Marine Fisheries Service

Introduction

The Navy's Manchester Fuel Depot (MFD), located at Orchard Point in southern Kitsap County, has supplied petroleum products to military vessels since World War II. Because of the generally poor condition and outmoded design of the MFD fuel pier, it was replaced with a new pier of comparable length. The replacement project involved dredging about 80,000 m^3 of material from the site of the new pier, constructing a new 390-m fuel pier, and removing the old pier. Pier replacement began in February 1991 and was completed in March 1993. Further details of the project are provided in Roni and Weitkamp (1996).

We began a monitoring program in 1991 to assess environmental conditions before, during, and after the pier's replacement. Monitoring included monthly water quality sampling (pH, temperature, salinity, turbidity, and dissolved oxygen) at stations around the pier, annual measurements of the distribution and density of eelgrass (*Zostera marina*) adjacent to the pier, and determination of nearshore fish community structure and abundance by beach seining on both sides of the pier at weekly or biweekly intervals during the period of expected chum salmon outmigration (mid-late March through mid June). Chum salmon were the focus of the fish study because of concerns that the pier replacement might affect their along-shore outmigration. Although water-quality measurements and beach seining were stopped when the monitoring project was completed in 1993, we have continued to monitor the eelgrass distribution and density each year since then, except in 1995.

This project has provided us with a unique opportunity to monitor closely a Puget Sound eelgrass bed and its associated fish community over several consecutive years. The changes and degree of interannual variability we observed far exceeded our expectations and would not have been obvious had we monitored for only one or two years, the typical length of similar monitoring projects. Because ecosystems are not often examined in ways that allow us to observe the natural range of variability, we often underestimate the variability of ecosystems. Consequently, in light of this uncertainty, caution should be used when basing long-term management decisions on short-term observations.

Results

Water Quality

Water-quality conditions, measured between 1991 and 1994 during pier replacement, were largely unaffected by pier construction. Typically, water qualities at sampling stations around the pier were no different from those at a control station about two km away. On several occasions turbidity increased slightly during active dredging, but the increase was restricted to the sampling station closest to the dredging and was apparently short-lived. As expected, water temperatures become colder in winter and warmer in summer. In 1992, water temperatures were several degrees warmer than in other years, presumably due to regional warming by the El Niño.

Eelgrass

As the new fuel pier was constructed and the old pier removed between 1991 and 1993, the distribution of eelgrass around the piers varied each year (Figure 1). Since 1993, when the pier replacement project was completed, the distribution of the eelgrass bed had gradually increased around the pier and spread seaward (Figure 1). In addition, several small patches of eelgrass observed in 1991–93 west of the pier were not all seen in 1994 or 1996 but reappeared in 1997.

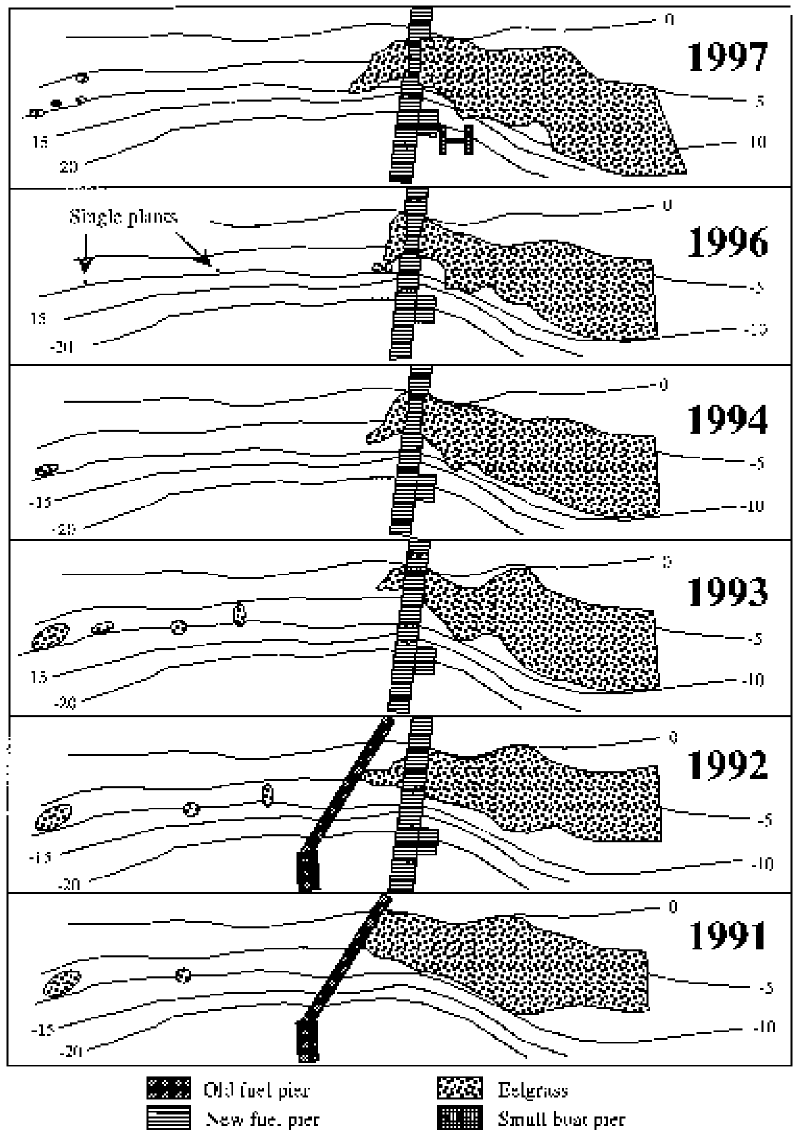

Figure 1. Approximate distribution of eelgrass near the Navy Fuel Piers, Manchester, Washington. The presence of old and new fuel piers during each survey is indicated. Contour lines are in feet below mean lower low water.

Table 1. Densities of reproductive and vegetative shoot densities from the large eelgrass bed directly east of the Navy's new Manchester fuel pier. NA = not available.

Year	Reproductive Shoots/m^2 (s.d.)	Vegetative Shoots/m^2 (s.d.)
1991	14.9 (5.0)	NA
1992	12.3 (8.1)	NA
1993	2.1 (3.2)	124 (NA)
1994	2.1 (2.4)	524 (251.9)
1996	4.6 (4.9)	402 (254.1)
1997	12.9 (9.7)	319 (164.9)

Densities of both vegetative and reproductive eelgrass shoots along transects east of the pier have also exhibited considerable interannual variability (Table 1). Reproductive shoots were abundant, exceeding 12 shoots/m^2 during 1991, 1992, and 1997, and largely absent (<5 shoots/m^2) in the intervening years. Vegetative shoot densities peaked in 1994 and have been declining since then (Table 1).

Nearshore Fish Community Composition and Abundance

During the three years of monitoring the nearshore fish community (1991–1993), 42 fish species were recorded, representing 17 families, including 10 species of Cottidae (sculpins), six species of Pleuronectidae (flatfishes), and five species of Salmonidae. Most fish identified were typical of Puget Sound intertidal beaches (Miller et al. 1975; Wingert and Miller 1979; Borton 1982). Some of the more unusual species caught included big skate (*Raja binoculata*), grunt sculpin (*Rhamphocottus richardsoni*), and tidepool snailfish (*Liparis florae*).

The number of fish species recorded and their seasonal abundance showed considerable interannual variation (Figure 2). For example, in 1993 very few fish (<400 fish/ha) representing only a few species were caught in beach seines between mid-late March and mid-May, while catches during that same period in 1991 and 1992 averaged 1,000–2,500 fish/ha and included almost twice as many species. From mid-May through mid-June, however, the situation switched, and in 1993 the numbers of fish and species caught exceeded that in 1991 and 1992.

The abundance and timing of juvenile chum salmon exhibited even more marked contrasts among years (Figure 2). The timing of peak juvenile chum salmon densities in 1992 occurred two months earlier than it did in 1993, while the peak abundance of chum salmon in 1993 was almost three times that in 1991.

Discussion

Whether the observed variation in the eelgrass bed and associated fish community was caused by the pier replacement project, by other factors such as environmental variation, or by some combination of the two is unclear. This is due to the lack of a consistent control site unaffected by pier construction, as well as possible undetected effects of the new pier on the nearshore environment. However, it is likely that some of the observed variability would be independent of pier effects while some may have been influenced, in part, by pier replacement.

Eelgrass beds naturally display considerable interannual variation in perimeter shape and position (Spratt 1989). Consequently, some of the distributional changes observed during monitoring are likely to reflect natural variation. Shading by barges (brought in to serve as work platforms for dredging and pile driving) and decreased water clarity during dredging may also have affected the eelgrass, particularly in areas of high disturbance. Since the project was completed in 1993, however, the position and shape of the eelgrass bed has continued to change. This continued change might be due to high natural variation independent of the pier replacement, continued effects of the new pier, or other factors. For example, the new pier appears to allow considerably more along-shore flow than did the old pier, and eelgrass is sensitive to currents (Fonseca et al. 1983, Phillips 1984). Although the source of this continued change is unknown, each year the boundary of the eelgrass bed continues to move several meters and small patches of eelgrass appear and disappear.

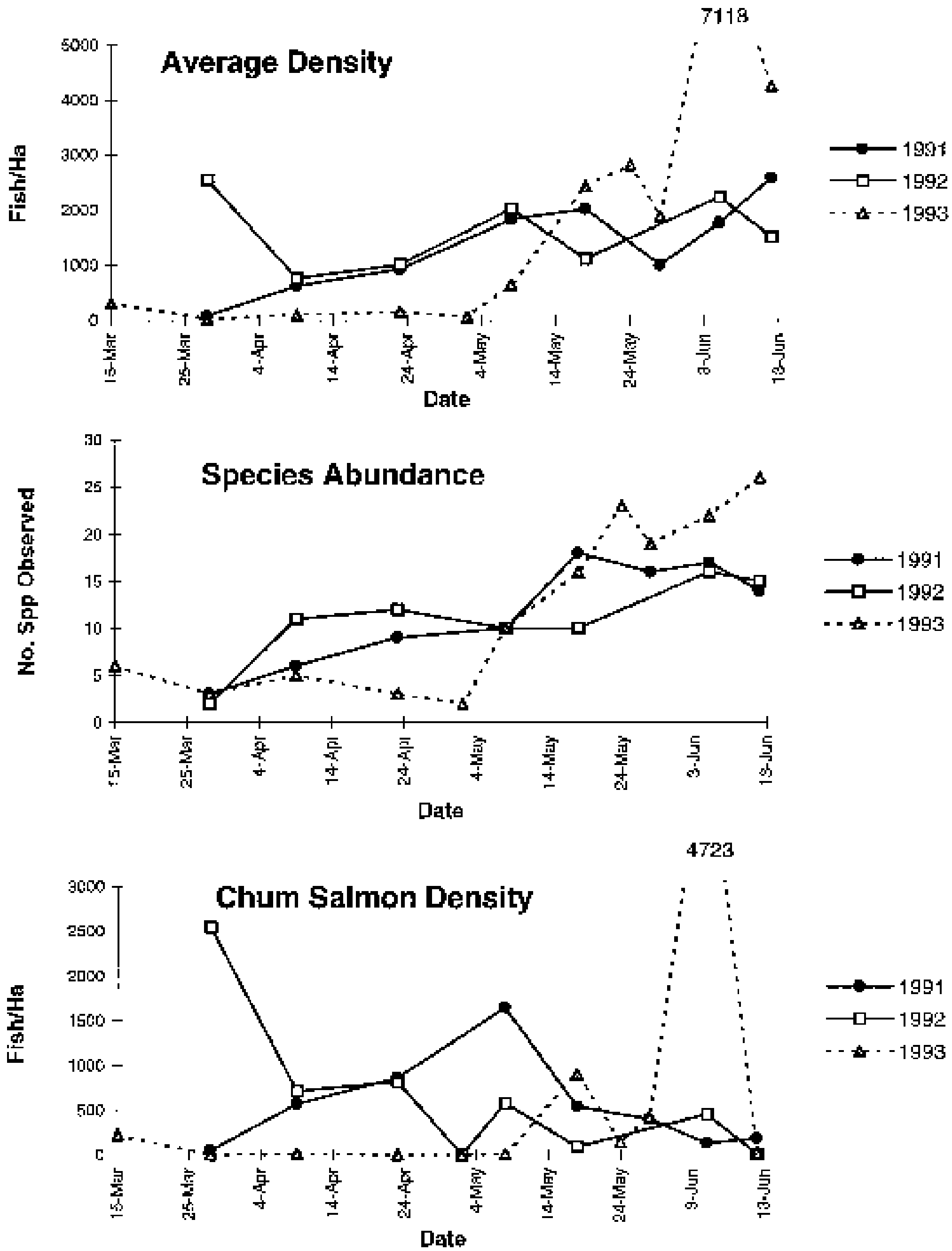

Figure 2. Results of beach seining at the Navy's Manchester fuel pier during spring 1991, 1992, and 1993: average density of all fish (top), total number of species identified (middle), and average density of chum salmon (bottom). The new pier was being built during 1991 and 1992, while seining in 1993 occurred after the old pier was removed and the project was completed.

Reproductive shoot densities recorded in the large eelgrass bed in 1993–96 (2–5 shoots/m^2) were much lower those measured in 1991, 1992, or 1997 (12–15 shoots/m^2), and lower than is typical for Puget Sound (6–66 shoots/m^2) (Phillips 1984) or Manchester eelgrass (5–9 shoots/m^2) (Phillips et al. 1983). Although this decline might be expected from the disturbance of pier replacement, it appears that at least the 1993 changes were independent of it. The production of reproductive shoots depends on numerous environmental parameters, including ambient light levels and temperature (Keddy 1987; Phillips et al. 1983; van Dijk et al. 1992), both of which are affected by weather. The spring of 1993 was one of the wettest and cloudiest on record in the Puget Sound region (WCIS 1998). In addition, reproductive shoot densities at two other eelgrass beds in Central Puget Sound were also low in 1993. This suggests that low reproductive shoot densities in 1993 were regional in scope and may have been influenced by the cool, wet weather rather than site-specific environmental disturbance due to pier replacement.

Comparisons of fish catches in 1991, 1992, and 1993 indicate that the greatest differences among years were found in the timings and magnitudes of peak densities and species richness. In contrast, average values for fish densities and species richness over this period were fairly similar. Fish, like other ectotherms, are temperature-sensitive and therefore differences in timing between years probably resulted primarily from natural variability in water temperature and weather rather than from anthropogenic factors associated with pier replacement. The magnitudes of peak densities and species richness, however, may have resulted from both anthropogenic and natural factors. For example, chum salmon have been observed to avoid pier construction sites (Bax et al. 1980) or in-water construction (Feist 1991), while tide stage strongly affects beach seine catches (Bax 1983; Borton 1982). In addition, water temperature may affect larval fish mortality, thereby influencing densities of juvenile fishes.

Consequently, exceptionally warm water temperatures in 1992 may explain the earlier timing of events in 1992 compared to 1991 or 1993. In contrast, the exceptionally high fish densities and species richness observed in 1993 may partially reflect improved environmental conditions around the fuel pier. Additional monitoring would be required to distinguish between natural variation in fish densities and species richness and improved environmental conditions associated with the new fuel pier.

Regardless of its source, the variability observed in the Manchester eelgrass bed and associated nearshore fish community greatly exceeded our expectations. Although we expected some changes in response to the pier replacement, we anticipated neither the magnitude of the interannual variability—such as the timing of peak chum salmon abundance—nor the continuing change in eelgrass long after project completion. Although our monitoring occurred during an extreme environmental event, an El Niño, such events are part of the natural variability experienced by Puget Sound ecosystems.

Nearshore communities, like other marine ecosystems, are commonly thought to be largely static entities, with predictable, seasonal changes. Our study, like previous studies examining interannual variability in eelgrass (Orth and Moore 1984; Spratt 1989; Olesen and Sand-Jensen 1994) and other macrophyte (e.g., Dayton and Tegner 1984) communities, reminds us that this is not necessarily the case—eelgrass patches may come and go, may change position or density, and their associated fish communities may be quite different from year to year. Consequently, what we observe one year may or may not hold true in subsequent years. Given this potentially high variability, it is especially important to use caution when basing long-term management decision on short-term observations. Ecosystems may not function or behave as expected when we base our expectations on a mere “snapshot” of a constantly changing entity.

Acknowledgments

This project benefited considerably from the expertise and assistance of B. Waknitz, B. Emmett, G. McCabe, E. Dawley, S. Hinton, and D. Dey, all of the NWFSC, NMFS. Considerable field assistance was provided by T. Parker, J. Butzerin and K. Neely, also from the NMFS. This project was funded by the U.S. Navy and NMFS.

References

Bax, N. J., E. O. Salo, and B. P. Snyder. 1980. Salmonid outmigration studies in Hood Canal. Final Report, Phase V to U.S. Navy from Fish. Res. Inst., School Fish., Univ. Wash., Seattle. 55 pp. (Available from Fisheries Research Institute, Univ. Washington, Seattle, WA 98195).

Bax, N. J. 1983. The early marine migration of juvenile chum salmon (*Oncorhynchus keta*) through Hood Canal--its variability and consequences. Ph.D. Dissertation, Univ. of Washington, Seattle, WA. 196 pp.

Borton, S. F. 1982. A structural comparison of fish assemblages from eelgrass and sand habitats at Alki Point, Washington. M.S. Thesis, Univ. of Washington, Seattle, WA. 85 pp.

Dayton, P. K., and M. J. Tegner. 1984. Catastrophic storms, El Niño, and patch stability in a southern California kelp community. Science 22(4646):283–385.

Feist, B. E. 1991. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. M.S. thesis. School Fish., Univ. Wash., Seattle, WA. 66 pp.

Fonseca, M. S., J. C. Zieman, G. W. Thayer, and J. S. Fisher. 1983. The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows. Estuar. Coast. Shelf Sci. 17:367–380.

Keddy, C. J. 1987. Reproduction of annual eelgrass: variation among habitats and comparison with perennial eelgrass (*Zostera marina* L.). Aquat. Bot. 27:243–256.

Miller, B. S., C. A. Simenstad, L. L. Moulton, K. L. Fresh, F. C. Funk, W. A. Karp, and S. F. Borton. 1977. Puget Sound baseline program nearshore fish survey, 168 pp. Final Report to the Washington State Department Ecology, contract 75-017, DOE Baseline study. (Available from Fisheries Research Institute, Univ. Washington, Seattle, WA 98195).

Olesen, B., and K. Sand-Jensen. Patch dynamics of eelgrass *Zostera marina*. Mar. Ecol. Prog. Ser. 106:147–156.

Orth, R. J., and K. A. Moore. 1984. Distribution and abundance of submerged aquatic vegetation in Chesapeake Bay: A historical perspective. Estuaries 7:531–540.

Phillips, R. C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. U.S. Fish Wildl. Serv. FWS/OBS-84/24. 85 pp.

Phillips, R. C., W. S. Grant, and C. P. McRoy. 1983. Reproductive strategies of eelgrass (*Zostera marina* L.). Aquat. Bot. 16:1–20.

Roni, P., and L. Weitkamp. 1996. Environmental monitoring of the Manchester naval fuel pier replacement, Puget Sound, Washington, 1991–1994. Report to Department of Navy, Contract N62474-91-MP-00758. 76 pp. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097).

Spratt, J. D. 1989. The distribution and density of eelgrass, *Zostera marina*, in Tomales Bay, California. Calif. Fish Game 75:204–212.

van Dijk, G. M., A. K. Brenkelaar, and R. Gijlstra. 1992. Impact of light climate history on seasonal dynamics of a field population of *Potomogeton pectinatus* L. during a three year period (1986–1988). Aquat. Bot. 43:17–41.

Western Climate Information System (WCIS). 1998. National Weather Service, Western Regional Climate Center, Reno, NV. Available through Internet at http://wrcc.sage.dri.edu/ (online database).

Wingert, R. C., and B. S. Miller. 1979. Distributional analysis of nearshore and demersal fish species groups and nearshore fish habitat associations in Puget Sound. Final Report to Wash. State Dept. Ecol., Contract No. 78-070 from Fish. Res. Inst., Univ. Wash., Seattle. 110 pp. (Available from Fisheries Research Institute, Univ. Washington, Seattle, WA 98195).